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Vineyards at the east end of Valle Guadalupe and chaparral-covered Sierra Blanca behind. *Quercus agrifolia* woodlands cover the far side of the basin and *Pinus coulteri* forest silhouettes the left summit on the skyline. Photographs by Richard A. Minnich.

MEDITERRANEAN VEGETATION OF NORTHERN BAJA CALIFORNIA

by Richard A. Minnich and Ernesto Franco-Vizcaino

THE UPPER peninsula of northern Baja California is covered by mediterranean grasslands, shrublands, and conifer forests similar to those of Alta California. At the same time, an enduring traditional land use system has given this region a distinctive relationship between man and nature that is unique within the Californian floristic province. Historical isolation has until recently protected the wildlands of northern Baja California, as most of its biological environment did not experience the intense exploitation that occurred in Alta California. Indeed, the vegetation has a pristine character rarely seen in Alta California. Fire control is practically nonexistent because much of the Peninsular Ranges is still accessible only by foot or horseback. Except in the mountain meadows, livestock grazing was limited by the low value and inaccessibility of vegetation.

Until a few decades ago Baja California was referred to in Mexico as the *frontera*. This term may seem incongruous for a modern state with large cities—Tijuana, Mexicali, and Ensenada—and extensive commercial agriculture in coastal lowlands and Valle Mexicali. Yet, until the end of World War II northern Baja California largely remained politically and economically isolated and undeveloped, despite its proximity to the rapidly expanding economy of Alta California. Within Mexico, the *frontera* was a distant outpost from Mexico City. This contrasts with Alta California's ecosystems over the past two centuries, where forests were logged for construction, fuel wood was culled for mining operations and domestic use, rangelands were heavily grazed by livestock, and fire suppression was imposed on wildlands during the twentieth century.

Differences in land use between California and Baja California have resulted in a significant divergence in the state of natural vegetation, and this is seen even in space imagery and NASA Highflight aerial photography. Ecosystems north of the U.S.-Mexican border have been so altered that ecologists find it difficult to determine the nature of past disturbance regimes, vegetation structure, and dynamics, while to the south chaparral and forests are reminiscent of the California landscape during the nineteenth century. The transborder differences in ecosystems may prove to be an ideal opportunity in ecological research by providing insight into the nature of historical vegetation change in California, as well as the dynamics of vegetation under traditional land use in Baja California.

The biota of northern Baja California is relatively unknown and unstudied compared to that of California. This introductory article briefly surveys the mediterranean ecosystems covering this region and provides an overview of possible effects of land use on these ecosystems in a traditional rural economy.

Northern Baja California is part of the Peninsular Range geomorphic province. Near the Pacific Coast is a rugged discontinuous chain of ranges (summit elevation 3,900 to 4,900 feet) that includes Cerro Bola and a north-to-south range east of the Ensenada plain. About 160 miles inland is the Sierra Juárez proper, a relatively undissected, westward-tilting plateau of greater elevation (3,900 to 5,900 feet). Between the coastal range and the Sierra Juárez is a series of inland basins, including Valle las Palmas, Valle Guadalupe, Valle Ojos Negros, and the plains between El Alamo and Santa Catarina. This area is bordered on the south by the Agua Blanca fault, which traces as a series of steep east/west-bearing transverse ranges (3,300 to 4,600 feet) from Punta Banda to Valle la Trinidad and Paso San Matías. Farther south is the Sierra San Pedro Martir, a spectacular fault-bound range of high plateaus capped by Picacho del Diablo (elevation 10,170 feet). The western front of this range has an extensive area of rugged foothills and mesas, rimmed along the coast by marine terraces.

Northern Baja California lies at the southern margin of the North American mediterranean climatic zone. Winter frontal storms bring rains between November and April. Summers are dry except for afternoon mountain thunderstorms. Mean annual precipitation ranges from eight to fourteen inches along the coast to sixteen inches on the summits of the near-coast ranges, eighteen to twenty inches on the western flank of the Sierra Juárez, and twenty to twenty-seven inches in the Sierra San Pedro Martir. The inland basins on the leeward side of the coastal ranges receive six and one-half to ten inches. It is estimated that the average annual water equivalent of snowfall in the Sierra Juárez is only twenty-five percent of the annual precipitation, even on the highest summits. In the Sierra San Pedro Martir snowfall exceeds fifty percent of the annual precipitation above 7,200 feet.

Vegetation Distribution

The vegetation of northern Baja California, mapped by interpreting a series of aerial photographs taken in 1956, 1972, and 1991, shows conspicuous vegetation zonation similar to that in California. This results from the elevation and rainshadows produced by the mountainous terrain of the peninsula. Exotic grassland and brushlands at lower elevations give way to forests in the highest mountains. Pinyon woodlands cover leeward slopes facing the Sonoran Desert.

Exotic Annual Grassland

Coastal plains and basin floors are covered by exotic grasses and forbs introduced mostly from lands surrounding the Mediterranean Sea. Dominant herbs include *Bromus rubens*, *B. mollis*, *B. diandrus*, *Avena barbata*, *Erodium cicutarium*, *Brassica geniculata*, and a few natives such as *Hemizonia* species. Grasslands are most widespread in deep, loamy soils and alluvium between Tijuana and Valle las Palmas, in uncultivated portions of Valle Guadalupe, and along the Ensenada plain. Grasslands also occupy inland basins from Valle la Palmas southward along a string of small basins to Valle Guadalupe, as well as portions of Valle Ojos Negros.

Exotic annuals apparently have covered the valley floors of northern Baja California since at least the mid-nineteenth century. In 1855 the U.S.-Mexican boundary survey reported that in coastal valleys of Southern California "the wild oat *Avena fatua* . . . is so extensively naturalized, that it gives every fertile tract the appearance of a cultivated field . . ." Orcutt describes exotics introduced a century before by Franciscan missionaries in bottomland habitats of northern Baja California. At San Vicente he noticed mustard, presumably *Brassica nigra*, used for

Laguna Hanson is encircled by Jeffrey pine forest.



Areas of Vegetation Types

(This survey begins with plant communities along the coast and works eastward and inland across the coastal ranges and inland basins to the Sierra Juarez and San Pedro Martir.)

Vegetation Type	Area (Acres) ¹	Vegetation Type	Area (Acres) ¹
Herbaceous communities		Hardwood forest	
Exotic annual grassland	190,264	Riparian forest	14,826
Mountain meadow	21,992	Coast live oak	61,279
Shrublands		Canyon live oak	22,486
Coastal sage scrub	13,870	Pacific Emory oak	29,650
Maritime desert scrub	756,363	Quaking aspen	1,147
Great Basin sage scrub	14,331	Conifer forest	
Chamise chaparral	769,212	Parry pinyon/red shank chaparral	145,045
Chamise/California juniper chaparral	452,680	Parry pinyon/chamise chaparral	186,064
Red shank chaparral	334,075	Parry pinyon/California juniper	29,899
Mixed chaparral	224,858	Parry pinyon/desert chaparral	131,208
Peninsula manzanita chaparral	29,157	Mixed parry pinyon/singleleaf pinyon	132,444
Timberland chaparral	52,365	Singleleaf pinyon	110,205
Mountain meadow	21,992	Jeffrey pine	117,865
Closed-cone conifer forest		Mixed Jeffrey pine	48,431
Knobcone pine	988	Mixed white fir	8,415
Bishop pine	<250	Incense-cedar	1,482
Tecate cypress	1,200	Mountain cypress	1,977
Arizona cypress	<100	Lodgepole pine	2,471
Coulter pine	1,730		

¹Calculated from the GIS.

construction of huts. He also described a thin cover of filaree (*Erodium cicutarium*) east of El Rosario and at an agricultural colony near San Quintín. *Trifolium* was also seen at San Quintín. William M. Gabb, in his report to J. Ross Browne in 1867, thought that the grassland in uncultivated parts of Valle Guadalupe, apparently *Avena fatua*, was unsurpassed in any part of northern Baja California. A second wave of exotics introduced during the 1890s, including *Bromus rubens*, *B. diandrus*, *Avena barbata*, and *Brassica geniculata*, have established ever-increasing cover especially after about 1950.

Exotic annuals seem to have occupied former areas of herbaceous cover observed at European contact in the late eighteenth century, similar to that described in Alta California. Widespread "pasture" and "meadows" were described in the diaries of Crespi and Serra at Valle San Vicente, Valle Santo Tomás, Ensenada, Valle Guadalupe, and coastal terraces south of Tijuana. Orcutt's records of his journeys into northern Baja California during the 1880s—before the arrival of second-wave exotics—indicate that the foothills and mesas at Tijuana, Ensenada, San Telmo Canyon, and east of El Rosario were extensively covered with wildflowers. During his travels along the coast he mentions many species in *Eschscholzia*, *Lasthenia*, *Layia*, *Phacelia*, *Delphinium*, *Astragalus*, *Cryptantha*, *Peri-*

style, *Oenothera*, *Camissonia*, *Lotus*, *Calochortus*, and *Pennstemon*. He did not mention *Stipa* or other native grasses. It is possible that the Franciscan exotics may have displaced native forbs rather than perennial *Stipa* bunch grasslands, similar to what occurred in the semi-arid southern San Joaquin Valley. The ambiguities of late eighteenth-century Spanish botany lend little insight into pre-European herbaceous vegetation. In their diaries Spanish explorers used the term *pasto*, which has been conventionally translated as grassland. It is really a cultural term that relates to forage suitable for livestock and is more correctly interpreted as "herbaceous cover." Hence, these accounts lend no first-hand evidence whether non-woody vegetation consisted of grasses or forbs.

Coastal Sage Scrub/Maritime Desert Scrub

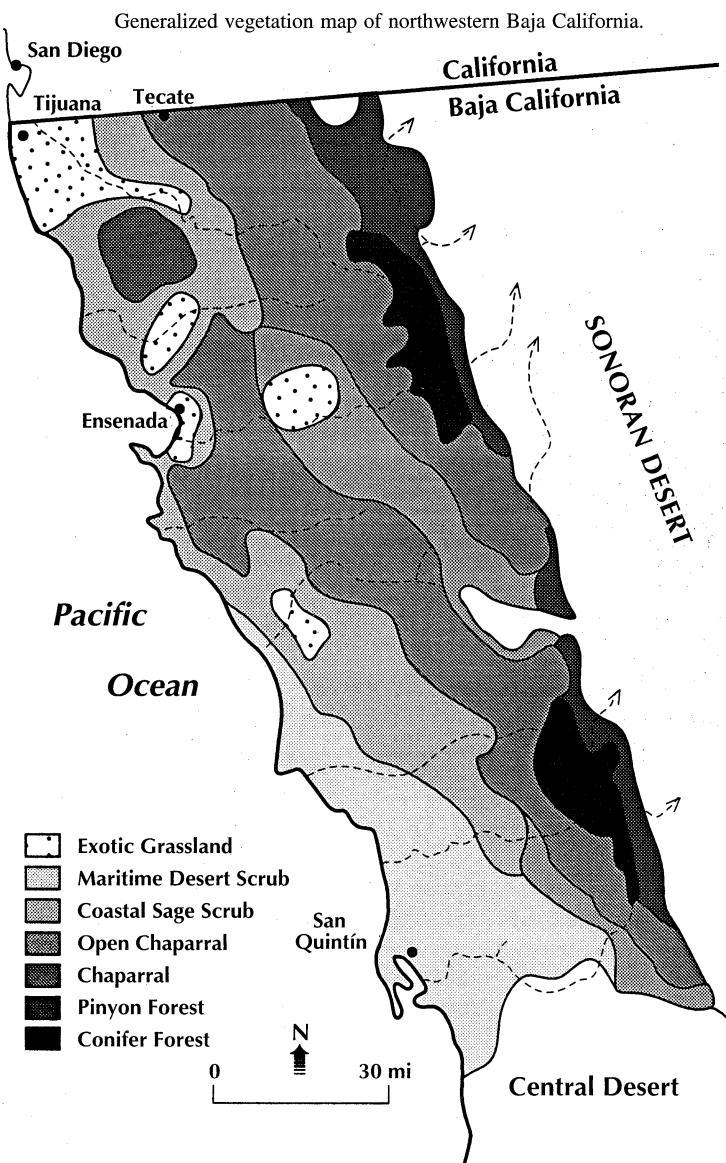
The foothills and lower mountain slopes below 3,200 feet are blanketed by coastal sage scrub, which consists of an open to contiguous mixture of aromatic, drought-deciduous subshrubs, mixed with a few deciduous and evergreen shrubs and a scattering of succulents. Coastal sage scrub is widespread in the coastal range from the international boundary southward to Santo Tomás and San Vi-

cente. It also extends into the inland basins north of Valle Guadalupe, on slopes surrounding San Vicente, and along the Sierra San Pedro Martir foothills east of the San Quintin coastal plain. Coastal sage scrub is nearly absent from the high inland basins of Ojos Negros, Santa Catarina, and Valle la Trinidad. Important subshrubs include *Artemisia californica*, *Eriogonum fasciculatum*, *Salvia munzii*, *S. mellifera*, *S. apiana*, *Lotus scoparius*, *Viguiera laciniata*, *Cneoridium dumosum*, and *Encelia californica*. South of Valle Descanso and Valle las Palmas two tall woody deciduous shrubs, *Fraxinus trifoliata* and *Aesculus parryi*, grow abundantly on north-facing exposures. Coastal sage scrub also contains a few evergreen sclerophyllous shrubs, notably *Malosma laurina*, *Rhus integrifolia*, and *Simmondsia chinensis*.

South of a line from Punta Banda to San Vicente, coastal sage scrub is replaced by maritime desert scrub, which also consists of uninterrupted cover of subshrubs, but is much richer in succulent taxa. Important species include the dominants of coastal sage scrub, as well as subshrubs having more southerly distributions, such as *Viguiera laciniata*, *Ambrosia chenopodiifolia*, *Rosa mi-*

nutifolia, and *Prunus fasciculata*. The most common evergreen shrubs are the desert species *Ephedra nevadensis* and *Simmondsia chinensis*, but *Malosma laurina* and *Rhus integrifolia* are still common along arroyos. Important cacti include *Bergerocactus emoryi*, *Machaerocereus gummosus*, *Myrtillocactus cochal*, *Mammillaria dioica*, and *Opuntia* species. Succulence is most pronounced on southern exposures. Near El Rosario maritime desert scrub grades into Sonoran Desert scrub. Here subshrubs become even more scattered and succulence is even more pronounced. In this area are the northernmost outposts of the well known "boojum tree" or *cirio* (*Fouquieria columnaris*) and *cardon* (*Pachycereus pringlei*), the two most conspicuous arboreal succulents of the Central Desert. Above 3,300 feet in the Sierra San Pedro Martir maritime desert scrub reverts to coastal sage scrub dominated by *Eriogonum fasciculatum* and *Salvia apiana*.

Coastal sage scrub and maritime desert scrub have been subjected to less land conversion pressure than in Southern California. Small areas have been converted for urbanization at Tijuana and Ensenada and along the coastal highway between the two cities. The largest threat has been land clearing for agriculture. The most recent example is the extensive conversion of maritime desert scrub for irrigated tomato plantations along the San Quintin coastal plain. At present, northern Baja California hosts the most extensive coastal sage scrub of the Californias.



Chaparral

With the possible exception of the Transverse and Peninsular ranges of Southern California, northern Baja California possesses the most extensive stands of chaparral along the Pacific Coast. The physical structure and species composition of this community shift with elevation, slope exposure, and distance from the Pacific Ocean. The coastal range, subject to modest winter rain and cool, foggy summers, hosts dense arboreal stands similar to those in the coastal Santa Ana, Santa Monica, Santa Inez, and Santa Lucia mountains of California. Coastal stands may have the greatest species diversity of all Baja California chaparral. *Adenostoma fasciculatum* (chamise) is dominant on south-facing slopes, with *Malosma laurina*, *Ceanothus verrucosus*, *C. greggii*, and *Ornithostaphylos oppositifolia* being common associates. North-facing slopes are dominated by *Ceanothus oliganthus*, especially in the mountains east of Ensenada. Also common are *Heteromeles arbutifolia*, *Comarostaphylos diversifolia*, *Xylococcus bicolor*, and *Rhus ovata*. *Cercocarpus betuloides* is important north of Ensenada. The endemic *Arctostaphylos bolensis* grows on the eastern flank of Cerro Bola. Drought-deciduous *Fraxinus trifoliata* and *Aesculus parryi* commonly grow with mixed chaparral below 3,300 feet. Red shank (*Adenostoma sparsifolium*) occurs locally on Sierra Blanca, near Valle Guadalupe, near Highway 3 west of

Ojos Negros, and on the peaks northwest of El Alamo. Because mean annual precipitation near the ocean decreases rapidly south of Santo Tomás, coastal stands become increasing patchy and restricted to northern exposures along the coast. Some patches, such as one near Colonet, survive on as little as six inches mean annual precipitation, likely because of abundant coastal fogs.

The semi-arid interior basins from Ojos Negros to Santa Catarina are covered with open stands of chamise in association with California juniper (*Juniperus californica*). These stands have many desert shrubs and succulents such as *Ephedra nevadensis*, *Simmondsia chinensis*, *Prunus fasciculata*, *P. fremontii*, *Acacia greggii*, and *Yucca schidigera*. This association is also widespread along the perimeter of Valle Trinidad and in the southern Sierra San Pedro Martir below 4,300 feet.

Farther inland the mesic western flanks of the Sierra Juárez and Sierra San Pedro Martir host a second belt of dense chaparral, but with lower species diversity than in the coastal range. Most stands consist chiefly of two species, *Adenostoma fasciculatum* and *Ceanothus greggii* var. *perplexans*, with intervening patches of red shank chaparral in areas with granitic substrate. While chamise chaparral may be found throughout the Sierra Juárez, *A. sparsifolium* is concentrated in the higher plateaus north of Santa Catarina, the west slope of the Sierra San Pedro Martir, and between El Alamo and Santa Catarina. In both communities other shrubs and succulents, such as *Rhus ovata*, *Arctostaphylos pungens*, *A. pringlei*, *Quercus dumosa*, *Eriogonum fasciculatum*, and *Yucca schidigera*, form only scattered cover, usually less than one percent. The highest elevations (3,900 feet) from Tecate to Laguna Hanson contain small areas of mixed chaparral dominated by *Ceanothus leucodermis*, *Arctostaphylos glandulosa*, and *A. glauca*. Farther south, in the Sierra Juárez and in the Sierra San Pedro Martir, mixed chaparral is replaced by peninsula manzanita chaparral dominated by monotypic stands of *Arctostaphylos peninsularis*.

The semi-arid eastern escarpments of the Peninsular Ranges between 3,200 and 7,600 feet are covered by open stands of desert chaparral that grow in association with forests of *Pinus quadrifolia* or *P. monophylla*. Common shrubs include *Quercus turbinella*, *Q. cornelius-mulleri*, *Q. cedrosensis*, *Rhus ovata*, *Rhamnus crocea*, *Prunus ilicifolia*, *Ceanothus greggii*, and leaf-succulents such as *Yucca schidigera*, *Nolina parryi*, and *Agave deserti*.

Evergreen oaks are surprisingly infrequent in the chaparral. *Quercus dumosa* is common only near Tecate and in the coastal range as far south as Ensenada. Among tree species, *Q. wislizenii* has been found only on Sierra Blanca, northwest of Laguna Hanson and at three locations on the west slope of the Sierra San Pedro Martir near 5,200 feet (for distributions of tree species in Baja California, see Minnich, 1987). *Q. chrysolepis* (canyon live oak), a small-leaved, shrubby form, grows on steep north-facing exposures and along canyons in the upper margin of the chapar-

ral belt. A few stands grow on the summits of the coastal range, including Sierra Blanca and Cerro Los Pinos. In the Sierra Juárez *Q. chrysolepis* is found on rocky summits rising above the Sierra Juárez plateau and the upper mesas of the southern volcanic tablelands. It is most widespread as understory in the mixed-conifer forests of the Sierra San Pedro Martir.

Chaparral is not limited to mediterranean climate zones of the peninsula. Stands may be found on mountain summits rising above the Central Desert, including the Sierra San Borja, Sierra Asamblea, Sierra Libertad, and Volcán las Tres Vírgenes. *Malosma laurina*, *Prunus ilicifolia*, and *Heteromeles arbutifolia* occur even farther south in the Sierra Giganta and Sierra Laguna.

The chaparral of the northern peninsula may be a "showcase" ecosystem that functions under natural disturbance. Without fire suppression fires are numerous and relatively small, whereas in California the reduction in the number of fires has led to fire enlargement and higher intensities. The inverse relationship between fire frequency and size is produced by a time-dependence in fire hazard, i.e., fire occurrence is self-limiting, related to gradual fuel build-up and increasing transpiration load during succession. Fire return periods are about the same in both countries, as most fires establish in old-growth stands (less than fifty years). Most burns form narrow overlap zones with recent burns that lack sufficient fuel to sustain flame lines. In other words, mosaics of fire-created patches are shaped by patch structure caused by previous fire history. The resulting pattern of patch turnover is spatially non-random and loosely self-organizing, such that future fires can be predicted from the patch mosaic.

Closed-Cone Conifer Forest

The chaparral covering the coastal range contains numerous small colonies of closed-cone conifer forest. Tecate cypress (*Cupressus guadalupensis* var. *forbesii*) is common on Otay Mountain and Tecate Peak along the international boundary, as well as in the Cerro Bola range and coastal mountains east of the Ensenada plain. According to R. Moran, this tree also occurs on a few summits southwest of San Vicente and in the foothills east of the San Quintín coastal plain. Arizona cypress (*Cupressus arizonica* var. *stephensonii*) grows locally along Cañada el Rincón and adjacent mesas east of Santa Catarina, in the southern Sierra Juárez. This population is apparently conspecific with the "Cuyamaca cypress" found on the west slope of Cuyamaca Peak in San Diego County.

Knobcone pine (*Pinus attenuata*) grows in the hills along the southern flank of Valle Guadalupe, with the largest stands on Cerro Miracielo. Other stands are found on Cerro los Pinos, thirty-five kilometers southeast of Ensenada, and on a summit south of Santo Tomás. Bishop pine (*P. muricata*) is found on coastal bluffs west of San

Vicente and has been reported by Gentry at Punta San Quintín. The partially serotinous Coulter pine (*Pinus coulteri*) is known from only six localities. Its only occurrence in the coast range is on Sierra Blanca (4,300 feet) near Valle Guadalupe. In the Sierra Juárez it grows west of Rancho San Faustino, on a summit northwest of Laguna Hanson, and on the volcanic mesas of Arroyo El Rincón. These colonies all grow between 3,900 and 4,900 feet. In the Sierra San Pedro Martir, *P. coulteri* is found in the far northern and southern extremities of the range, so far removed from the primary trails that they were not discovered until 1986.

Repeat aerial photographs of Baja California show that *Cupressus guadalupensis* ssp. *forbesii* and *Pinus attenuata* form even-aged stands in varying degrees of co-maturity with chaparral patch structure. This suggests that these conifers have fared well under a regime of stand-replacement burns during the present century. Several studies in California indicate that stand-replacement fires may be characteristic of closed-cone forests owing to their association with abundant and continuous chaparral fuels (Vale 1979; Borchart, 1985). These trees also respond with high reproductive effort and colonizing ability (reviewed by Vogl et al., 1988), as seedlings germinate from seed retained in serotinous cones of fire-killed parent trees. These trees may be unaffected by higher fire intensities due to suppression. Fire perimeter data for Baja California reveals that fires seldom recur within twenty years in spite of high fire frequencies (events/area).

The greatest threat to closed-cone forests of Baja California may be from wood cutting and gathering. However, most stands appear to be protected by impenetrable chaparral. The frequent occurrence of place names such as Cipres and Pino on Mexican DETENAL topographic sheets

Pinyon forest of *Pinus quadrifolia* and *P. monophylla* occurs on the La Rumorosa-El Topo plateau.



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confirms that these forests are prized as an important resource by Mexicans. It is common on ranches to see native cypresses carefully pruned into trees.

Perhaps the greatest value of closed-cone conifers is as a genetic resource. Fragmented closed-cone conifer forests in northern Baja California may have been long isolated from neighboring populations in California. For example, Moran (1977) observed that the cones of *P. coulteri* in the southern Sierra Juárez were unusually small for the species. Tom Ledig, a forest geneticist at the Pacific Southwest Forest and Range Experiment Station in Berkeley, California, states that there is more genetic diversity among the few *P. coulteri* populations of northern Baja California than in all the forests in California. He suggests that only one race spread northward into California after the last glaciation. In cursory observations of *P. attenuata* on Cerro los Pinos, the trees appear to be unusually tall and have a narrow, short branch spread compared to those in California.

Riparian Forest

Tall forests at lower elevations of northern Baja California are limited to riparian ecosystems and oak woodlands along stream courses and washes. *Populus fremontii*, *Platanus racemosa*, and *Salix* spp. are found throughout the peninsular and coastal ranges of northern Baja California. *P. fremontii* and *Salix* spp. also grow in drainages facing the Sonoran desert, as well as in the Colorado River delta. Oases of *Washingtonia filifera* and *Brahea armata* appear at wet sites in many desert arroyos on the eastern escarpment of the Sierra Juárez, as well as on both the eastern and western flanks of the southern Sierra San Pedro Martir. Orcutt (1883) first reported an isolated grove of *W. filifera* on the Pacific slope at Valle las Palmas. Other riparian trees are rare. *Populus trichocarpa* occurs in the Sierra San Pedro Martir at Arroyo la Grulla and along Rio San Rafael. *Fraxinus velutina* has been collected only along desert arroyos in the southern part of that range.

The diversity of riparian forests in northern Baja California is low compared to that in California. Several California trees nearly reach the international boundary but do not occur on the Mexican side. The southern limits of *Acer macrophyllum* and *Umbellularia californica* are in San Diego County. *Alnus rhombifolia*, which also occurs as far south as San Diego County at Mount Cuyamaca, has been erroneously reported to be in northern Baja California. This may be based on a mistranslation of *aliso* in eighteenth-century Spanish diaries. In Mexico this word customarily translates as alder, but may also refer to *Platanus* species. From our observations, reports of *aliso* by Spanish diarists consistently refer to colonies of *Platanus racemosa*. Likewise, the Spanish use of *madroño* may be the basis for listing of *Arbutus menziesii* as a common species in the Sierra Juárez and Sierra San Pedro Martir. However, *A. menziesii* has not been collected in Baja

California (the southern limit is on Mount Palomar in San Diego County, according to Griffin and Critchfield, 1976). We believe the Spanish diarists were referring to *Arctostaphylos* spp., which have foliage, inflorescences, and smooth reddish-brown bark similar to the strawberry tree (*Arbutus unedo*, strawberry madrone) found throughout the Mediterranean, including Old Spain, or perhaps *Arbutus andrachne*, which occurs in the eastern Mediterranean basin.

The impoverished riparian forest flora of northern Baja California may be related to the frequent catastrophic removal of stands from natural climatic variability. Riparian species are known for long-range seed dispersal as an adaptation for vicariant establishment resulting from the fragmentation of suitable moist habitats in arid lands. Because Baja California lies along the equatorward margin of winter frontal storms, droughts severe enough to parch even stream courses may be particularly significant in the region. Indeed, the frequency of winters without significant rain increases from perhaps once a century near the U.S.-Mexican border to once in ten years at San Quintín. The most widespread riparian trees, *Populus fremontii* and *Salix* species, have wind-borne seeds and are capable of rapid establishment of new colonies by long-distance seed dispersal. Recolonization may be less efficient among heavy winged-seeded species or trees with fruits, and this may explain their absence from Baja California. Only *Platanus racemosa* survives along the Pacific Coast, mostly north of San Vicente.

Oak Woodland

Coast live oak (*Quercus agrifolia*) is mostly confined to streams and margins of basins, in contrast with the extensive woodlands in the coastal ranges of California. Coast live oak is most common on the western flank of the Sierra Juárez southward to Laguna Hanson and in the coast range southward to Santo Tomás. Widely scattered stands occur in the transverse range from Santo Tomás to near Valle la Trinidad. The species then finds its southern limit along the western escarpment of the Sierra San Pedro Mártir. Although numerous small colonies of San Diego County blue oak (*Quercus engelmannii*) exist within half a mile of the U.S. side of the boundary, only one stand exists on the Mexican side, two and a half miles south of Tecate.

Over the past forty years Mexican conservation practices have highlighted the protection of species in *Quercus*, which reaches its greatest diversity in the country. Conservation practices arose in part from centuries of intense exploitation of oaks in central Mexico. In Baja California the impact of wood cutting for domestic fuel was probably local and of little regional significance because the introduction and use of natural gas and propane for heating and cooking predates the population explosion that occurred in the border cities after World War II. However, *Q.*

engelmannii may have been extirpated from the Sierra Juárez near the international boundary, especially near Tecate, where the demand for fuel may have been intense. *Q. engelmannii* may be easily removed because it is a poor sprouter after disturbance, typical of deciduous oaks, and would fare poorly from pollarding. It is still questionable whether *Q. engelmannii* was ever plentiful on the Mexican side. Although blue oak woodlands are common in San Diego County from Mt. Palomar to the west slope of Mount Cuyamaca, the tree becomes infrequent south of Interstate 8.

Time-series aerial photographs of Baja California since 1938 reveal little evidence that *Quercus agrifolia* was cut for firewood or construction, although intense grazing in basins near populated areas appears to prevent recruitment. An example would be forests between Tecate and Neji, which comprise very open parks of old-growth trees. On the other hand, remote stands such as those along Arroyo el Barbón and on the west base of the Sierra San Pedro Mártir are experiencing heavy recruitment.

Pinyon Forest

The inland Peninsular Ranges above 4,300 feet contain widespread forests of two pinyon pines, *Pinus quadrifolia* (Parry pinyon) and *P. monophylla*. Northern Baja California is the center of distribution of *P. quadrifolia*, as only scattered stands exist north of the international border in the Laguna Mountains of San Diego County and in the San Jacinto Mountains. *P. quadrifolia* grows in small, compact groves in dense stands of mature chamise, red shank, or peninsula manzanita chaparral. Patches may be found on the crest of the Sierra Juárez, interior basins from Ojos Negros to Santa Catarina, tablelands of the southern Sierra Juárez, and the west flank of the Sierra San Pedro Mártir, the southern limit of the species. Continuous pinyon forests in association with desert chaparral lie on the eastern escarpments of the Peninsular Ranges with dominance shifting from *P. quadrifolia* to *P. monophylla* toward the desert edge. The largest stand of *P. quadrifolia* grows on the upper eastern escarpment of the Sierra San Pedro Mártir above 6,600 feet.

The broad distribution of pinyon forest in northern Baja California was known by the late nineteenth century. Lemmon reported in the *Lower Californian* (June 3, 1892) that "pinyon forests, composed of a nut pine (*Pinus parryana*, *Pinus quadrifolia*)" began "a few miles south of the boundary . . . and extend southward along the backbone of the peninsula, with only an occasional break, to the south end of the Sierra San Pedro de Mártir." It was also reported that "along the precipices overlooking the desert another Pinon pine (*Pinus monophylla*) maintains a precarious existence."

The fire regime of pinyon forests without fire control has been one of long-period stand-replacement fires at

intervals from 125 years to several centuries, similar to that in California. Long fire intervals are due to the low productivity of this semi-arid ecosystem. Fragmented *Pinus quadrifolia* forests on the Pacific slope probably burn at fifty- to seventy-year intervals, similar to chaparral.

The major use of this ecosystem by Native Americans was the autumn harvest of pinyon nuts. The surviving Paipai and Kiliwa gathered pinyon nuts in the mountains near Paso San Matías. The Kiliwa ceased to harvest the nuts about a decade ago when their pinyon stand was apparently burned by arson, but the Paipai continue that activity to the present day. European land uses doubtless had local impact on this ecosystem. *Pinus quadrifolia* and *Juniperus californica* were utilized for construction and as fuel in smelting kilns in late nineteenth-century gold strikes at Japá, Tres Pozos, and El Alamo. However, demands for fuel wood for such processes as smelting, running stamps, pumps, and ore crushers were limited because nearly all of the gold discoveries were placers. All the mines played out within a few years of discovery. Pinyon forests along crestal plateaus of the Sierra Juárez are now occupied by a few cattle ranches, while stands on the eastern escarpment of the Sierra San Pedro Martir have never been settled. Cattle ranchers have utilized pinyons, as well as *Juniperus californica* and *Adenostoma sparsifolium* for fence posts and corral construction since the early nineteenth century, but the impact from the construction and maintenance of such infrastructure is unknown. Wood utilization may have been light because most of the mountains have remained in open range until recently. Most fencing was built to subdivide prime meadows and ranchsteads.

We have observed local harvest of pinyon in the Sierra San Pedro Martir for use as fuel at San Felipe. However, the low demand for wood and the increased use of fossil fuels seems to be limiting the exploitation of these trees. Transportation distance has become the most important limitation, as wood gathering at distances greater than six miles is regarded as unprofitable.

Mixed-Conifer Forest

The highest elevations of the Peninsular Ranges are covered by Californian mixed-conifer forests. In the Sierra Juárez above 4,300 feet monotypic stands of Jeffrey pine (*Pinus jeffreyi*) grow in basin floors and along margins of meadows. Forests span a distance of thirty-seven miles from sixteen miles southeast of Tecate to Arroyo Rincón near Santa Catarina, with the largest stands near Laguna Hanson. A few colonies of *Calocedrus decurrens* grow with the pines at wet meadow sites near Laguna Hanson and on the plateau nine miles south of the lake. Forests in the Sierra San Pedro Martir between 4,900 and 6,600 feet are also dominated by *Pinus jeffreyi*, with most stands growing in basins. Above 6,900 feet are extensive

mixed-conifer forests covering slopes as well as basin floors, similar to forests in the southern coast ranges and Sierra Nevada of California. South-facing slopes are covered with *P. jeffreyi* mixed with white fir (*Abies concolor*) and sugar pine (*P. lambertiana*), while *A. concolor* and *P. lambertiana* are dominant on steep northern exposures. Mixed-conifer forest is joined by the endemic mountain cypress (*Cupressus montana*) on the upper eastern escarpment from Cerro Venado Blanco to east of La Encantada, while lodgepole pine (*Pinus contorta*) is common near meadows and along arroyos at Vallecitos. Incense-cedar (*Calocedrus decurrens*) is found along water courses, especially on the western slope of the range. Quaking aspen (*Populus tremuloides*) is found at wet sites throughout the Sierra San Pedro Martir plateau above 7,600 feet. The forest floor contains open shrub cover dominated by *Arctostaphylos patula*, *A. pringlei*, *A. pungens*, *Ceanothus cordulatus*, *Quercus chrysolepis*, *Q. peninsularis*, *Artemesia tridentata*, *Salvia pachyphyllea*, and *Symphoricarpos parishii*. Mixed-conifer forest of the Sierra San Pedro Martir is unique to Mexico, as all coniferous tree species with the exception of white fir have ranges in this country limited to northern Baja California. White fir extends southward from the Rocky Mountains to the Sierra Madre Occidental of Durango.

Moderately intense surface fires as large as 12,000 acres (5,000 hectares) and with recurrence intervals of about fifty years alternately spread and smoulder mixed-conifer forests to this day, with some burns persisting weeks or months. Recurrent fire is the primary reason for the openness of forests in SSPM. Similar to forests described in California before fire control, stands on the Mexican side are dominated by heterogeneous mixtures of old-growth and pole-size pines with densities of 125 to 375 stems per acre (50-150 stems ha⁻¹). Chronosequence data show a gradual recruitment of saplings to pole-size status between fire cycles, but most are selectively eliminated from flame lines sufficient to defoliate canopies up to sixteen to fifty feet. The rate of entry into the overstory class is apparently balanced by mortality rates in the overstory class. Almost 100 years before, in 1888, the Sierra San Pedro Martir forests were examined in detail in an extraordinary seventy-six-day survey by Col. D.K. Allen, land inspector for the International [Colonization] Company. He recorded similar stand densities and stem diameter distributions as our survey. The open structure of forests at this time was also photographically confirmed by the 1906 Biological Survey.

In contrast, the past century of fire suppression in California mixed-conifer forests has led to rapidly increasing fire intervals, stand thickening, and build-up of understory fuels, with many forests showing an age-specific trend away from dominance by mature *Pinus ponderosa* or *P. jeffreyi* and toward dominance by juvenile, pole-size classes of *Abies concolor* and *Calocedrus decurrens*. In replicating sixty-eight field quadrants of

the Californian Vegetation Type Map (VTM) Survey taken in 1929-34 in the San Bernardino Mountains of Southern California, we have shown that sixty years of suppression has caused stem density increases of 250 to 500 stems per acre (100-200 stems ha⁻¹, dbh >10 cm), with thickening rates directly proportional to mean annual precipitation. Moreover, the original survey gave tree densities of 80-180 ha⁻¹, well within the range of modern SSPM densities. Post-suppression increases in fuel loadings and vertical fuel ladders have shifted the fire regime from patchy surface fires to extensive stand-replacement fires. Recent examples of stand-replacement large canopy fires may be found in the Sierra Nevada and coastal ranges of southern California at Yosemite and in Stanislaus National Forest. Many such burns have exceeded 250,000 acres, or an order of magnitude greater than any burn in SSPM. We attribute large fire sizes in California to lengthening fire intervals combined with reduced frequencies, which have served to increase fuel build-up and increase the uniformity of patch structure, similar to Californian chaparral.

Historically, low human population densities and the inaccessibility of the pine forests in Baja California have prevented significant removal of timber during the past two centuries. In the Sierra Juárez pine forests were logged during the mining booms at Japá and El Alamo. The International Colonization Company built a road from El Alamo to the forests at La Tableta (sixteen miles south of Laguna Hanson), where the company constructed a steam sawmill with the goal to supply 10,000 board feet of lumber per day to the mining camps at El Alamo (*Lower*

Californian, August 1, 1889, May 9, 1890). However, the La Tableta mill probably lasted only the few years of the El Alamo strike and had little lasting impact on the forest there. The Ejido Sierra Juárez established a gasoline saw-mill at Arroyo del Sauz, five kilometers south of Laguna Hanson in the 1930s, and ran a limited logging operation in the Jeffrey pine forests but the mill shut down during the 1980s.

The forests of the Sierra San Pedro Martir have never been logged. However, external economic interests, such as those related to logging, also endanger local forms of livelihood and open up the timber and wildlife resources of the Sierra to the international market. In particular, the pressure on U.S. timber companies to close down operations in California due to the spotted owl controversy has led them to look south for new logging sites. Recently, *La Jornada*, a major newspaper in Mexico City, reported that a concession for exploitation of the biological resources of the Sierra San Pedro Martir had been given to Diamond Mountain Resources, a firm in Amador County, California. The sustainable use of forests, however, requires consideration of appropriate logging procedures. Economic incentives encourage the cutting of as many large trees as possible, reversing normal forest dynamics by encouraging recruitment to young stems. But such recruitment does not assure the recovery of a forest because the abundance and low stature of saplings and pole-size trees increases the potential for stand-replacement fires, and claims that suppression protects forest by reducing fire occurrences are groundless. Forest harvesting in Californian mixed-conifer forest must recognize

Chamise and manzanita chaparral both occur in Arroyo el Barbón on the west slope of the Sierra Juárez.



that a mature tree is a small residual from the selective elimination by fire of hundreds or perhaps thousands of young individuals.

Will this Rich Resource Remain?

The isolation of northern Baja California is now being undermined by economic development. Although urban and agricultural growth was formerly concentrated in the rich Mexicali Valley and the border cities, the opening of the trans-peninsular highway, as well as Highway 3 from Ensenada to San Felipe during the 1970s, has contributed to the rapid growth of agriculture and establishment of *ejidos* and villages along the San Quintín coastal plain and San Telmo Valley. Secondary roads have been built into the Sierra Juárez and to the National Observatory in the Sierra San Pedro Martir.

The increasing accessibility of the region presents both threats and opportunities. One threat is the prospect that management systems of industrialized countries, such as fire suppression, will be introduced, which may result in irreversible changes that will make Baja California ecosystems indistinguishable from those in Alta California.

The maintenance of ecosystems or the restoration of altered ecosystems requires knowledge of the past. Future land management in Baja California should critically examine the well-managed status of ecosystems in the northern peninsula: the fragmentation of brushlands by small fires and the openness of conifer forests, resistant to catastrophic fires. Parts of Baja California probably duplicate a nineteenth-century landscape of California, against which management systems can be compared. Indeed, the northern Peninsula could be a showcase of ecosystems functioning under natural disturbance and traditional management systems for comparison with similar temperate ecosystems in Alta California. The region is an extraordinary resource for ecological research.

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